Vol. 9, No. 4 July-August, 1947

THE OSCILLOGRAPHER

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AN ALL-PURPOSE SCREEN FOR HIGH-VOLTAGE CATHODE-RAY TUBES

By Rudolf Feldt

During the last decade, the number of screen materials required for cathode-ray tubes has grown steadily with the increase in applications for cathode-ray oscillographs, and the requirements of radar and other systems. As a result there is a wide choice of types of fluorescent screens available having various specialized characteristics. It is the purpose of this article to evaluate certain of these screens for use in high-voltage cathode-ray tubes.

In the early days of Allen B. Du Mont Laboratories, Inc., natural zinc orthosilicate ore, known as willemite, was brought from Franklin Furnace in New Jersey to the plant, smashed by hammer, and sorted to obtain the best parts of the green fluorescent material for screen manufacture. Today, the zinc orthosilicate, produced synthetically and of considerably improved uniformity and quality, is used for the screen type which bears the RMA designation P1. Because of its high light output and great stability in operation, this screen material is used in most cathode-ray tubes employed in oscillographic applications.

In addition to the P1 screen, numerous other screen types have been standardized. The following types are manufactured by Du Mont for use at medium voltages (1000-4000 volts):*

P1 green, medium-persistence.
P2 yellow-green, long-persistence.
P4 white, medium-persistence (used mainly for television).
P5 blue-violet, short-persistence (upon special order only).
P7 yellow, long-persistence.
P11 blue, short-persistence.

This diversity of screen types makes it possible to obtain the best efficiency by the choice of the proper type of screen for each application. It is for this reason that Du Mont has spent much time and effort in the study of screen characteristics, and in the maintenance of a stock of all standard-type cathode-ray tubes. Du Mont customers have the convenience of a choice of various screen types; for instance, a P1 for visual observation, a P11 for photographic recording, and a P2 or P7 for applications where long persistence is required. Since many of these types are needed in limited quantities, the manufacturing costs are considerably higher than those for the standard types.

Several years ago, when Du Mont pioneered in the development of high-voltage cathode-ray tubes,[1, 2, 3] a thorough investigation of screen-material performance at high voltage was conducted in order to extend the use of these tubes into the field of very-high frequencies, the study of surge voltages, high-speed photographic recording, and projection oscillography.[4, 5] In addition, visual and photographic efficiency, persistence, sta-

* More details are given in the pamphlet entitled "Cathode-Ray Tube Screens and their Characteristics" which is obtainable upon request from our Technical Publications Department.

bility, screen burning, and other pertinent data were carefully studied.

The results of this investigation showed the surprisingly low efficiency of certain standardized screen types when operated at high accelerating voltage, while other screen materials became very efficient. It was found that a specific screen type, the P2, could be used as a single, all-purpose screen material for high-voltage oscillographic tubes. The versatility of this screen type appears from the following list of possible applications:

Visual observation of repetitive phenomena (medium persistence).
Projection oscillography (medium persistence).
Visual observation of single transients, including very fast phenomena (long persistence).
Photographic recording (short persistence).

Obviously, the existence of such an all-purpose screen type greatly simplifies both the users' and manufacturers' problems. Its various applications and properties will be discussed in detail in the following paragraphs.

Basically, the P2 screen material is zinc cadmium sulphide which has a spectral range extending from violet to orange (4000-6000 Å.) The spectrum of its light output is composed of two components, a short-persistent blue and a long-persistent yellow-green. The spectral distribution of the emission radiation of the P2 screen is shown in Figure 1. It can be seen that this screen material has a first peak in the blue region near 4500 Å and a second in the yellow region near 5300 Å. The relative amplitude of these two components depends on the mode of excitation of the screen material. By means of suitable color filters and other factors, it is possible to select and to combine the desirable properties according to need. The useful range of the P2 screen as an all-purpose screen extends from approximately 5 to at least 35 kilovolts.

Visual Observation of Repetitive Phenomena (Medium-Persistence)

At low voltage, the P1 screen is the most efficient screen type for visual observation. The persistence, or afterglow, of the P1 screen is medium (about 30 milliseconds for a decay to 10% of its initial intensity). This is sufficient to decrease flicker at low frequencies and still avoid a "smear" when rapidly-changing phenomena are

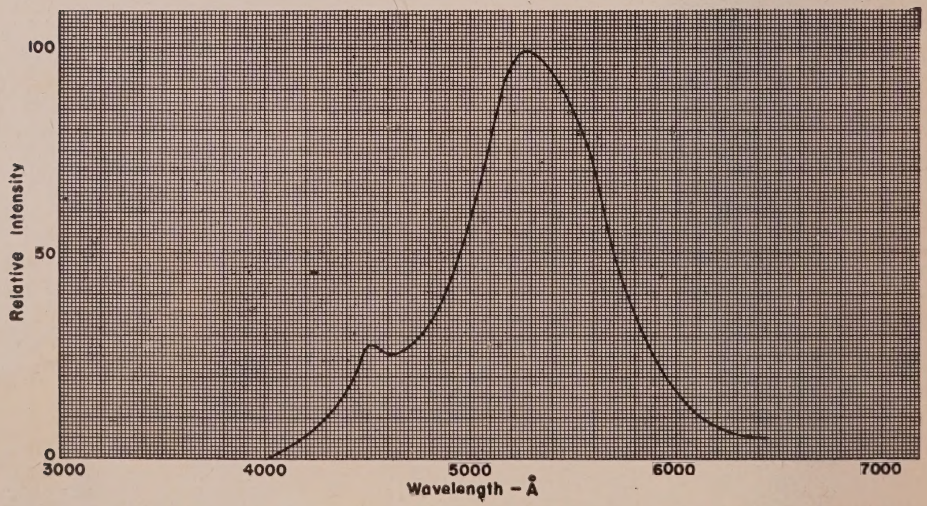

FIGURE 1—Spectral Distribution of the Emission Radiation of the Type P2 Screen.

observed. Fig. 2 shows a comparison of the P1 and P2 screens over the whole voltage range from zero to 35 kilovolts. The data constitute the average of several 5RP1A and 5RP2A tubes for the same beam currents. It appears from this graph that at 2.5 kv the two screen types have about the same efficiency. From this cross-over point, the P2 screen is always more efficient. At 10 kv its efficiency is 50% better than that of the P1. However, this high efficiency would not be sufficient to make the type P2 equivalent to the P1 screen, since the P1 is a medium and the P2 a long-persistence screen. The phosphorescence of these screen materials is, however, dependent on their temperature in such a way that the higher the temperature, the shorter is the persistence. For recurrent phenomena, the heat generated by the bombardment of the screen by high-voltage electrons is sufficient to quench the phosphorescence nearly completely. The screen thus performs under these conditions as a medium-persistence screen type. If in certain cases this persistence is still excessive, it can be eliminated to any desired degree by the use of blue transmitting filters, since the phosphorescent color is yellow.

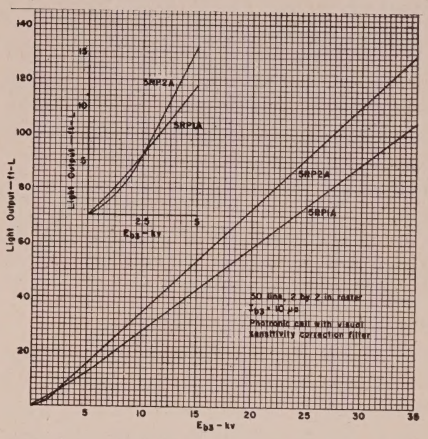

FIGURE 2—Comparison of Average Light Output of the Type 5RP1A and 5RP2A Tubes.

Figure 3 shows another interesting advantage of the P2 phosphor over the P1. With increasing signal frequency, a color shift towards the peak sensitivity of the human eye takes place which further improves the relative advantage of the P2 screen. This is due to the fact that the blue and yellow components of the light radiation of the Type P2 phosphor have unequal rise and decay times. Briefly, the blue component builds up very rapidly, while the yellow one increases slowly. Since the

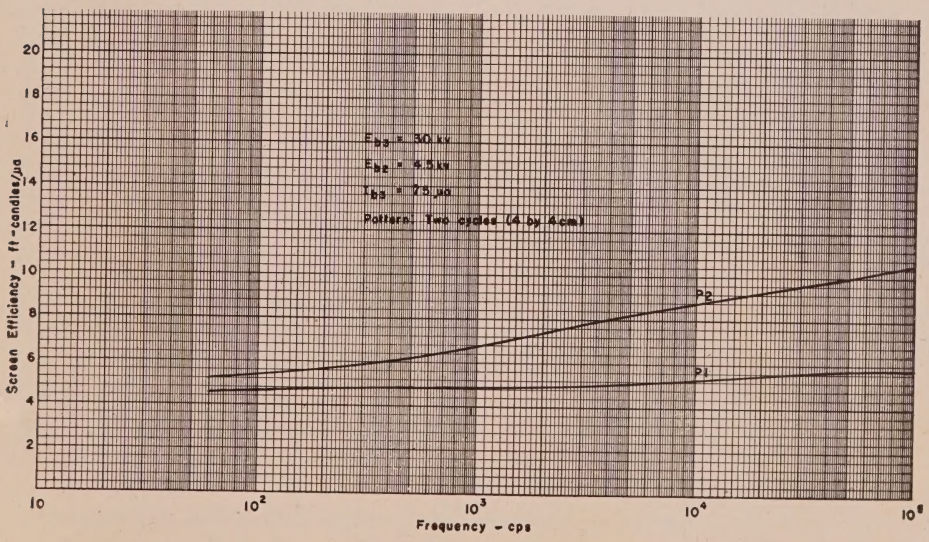

FIGURE 3—Variation of P1- and P2- Screen Efficiencies with Frequency.

color of this phosphor depends on the ratio of the blue to the yellow components, this color is changing with the mode of excitation, i.e., with signal frequency. The P1 and P2 phosphors are compared in Figure 3 for relative increase of light output with increasing signal frequency at the same voltage and beam current. The results demonstrate that the P2 screen is about twice as efficient as the P1 screen for high-frequency signals.

Projection Oscillography

Conditions and advantages of the P2 screen for projection as compared with the P1 are similar to those outlined in the previous paragraph, i.e., the light output of the P2 type is at least 50% higher than that of the P1. The relative intensity of the long-persistent yellow component is so low that for all practical purposes, it can be neglected in the projected picture, and the screen material performs as a medium-or short-persistence screen.

Visual Observation of Single Transients

For applications in which long persistence of the screen pattern is required, i.e., particularly for study of transient phenomena, both the type P2 and P7 screens are used presently at low voltage.[6] However, for very fast phenomena such as lightning discharges, surge voltages and other pulses, of a duration of the order of microseconds, the persistence obtainable at low voltage is entirely unsatisfactory. In the case of such fast non-repetitive transients the temperature of the screen material has insufficient time to rise and consequently, no quenching action takes place. It is therefore possible to increase the amount of phosphorescence considerably by increasing the voltage on the

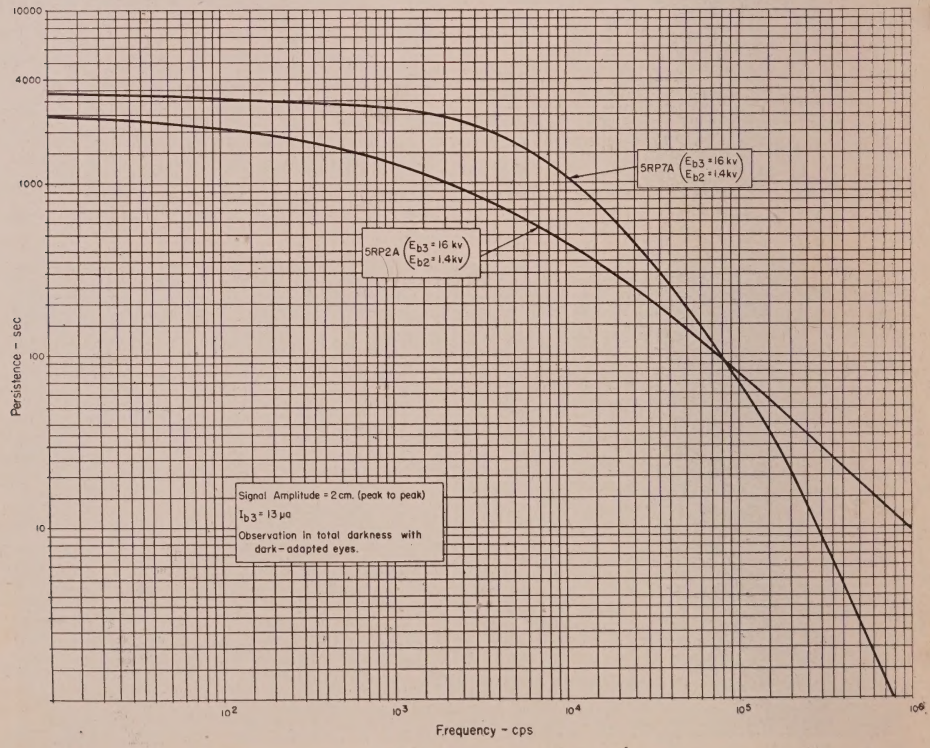

FIGURE 4—Persistence versus Writing Rate for Single Transients on the Type 5RP2 and 5RP7 Tubes.

tube. Figure 4 shows a comparison of the two long-persistent screens (types P2 and P7) at high voltage. This graph represents persistence time in seconds versus writing rate (frequency) for a single transient. This comparison clearly shows the superiority of the P2 screen for the observation of high-frequency phenomena. In fact, it is possible to obtain a persistence time of the order of one second for single transients of approximately 50 megacycles per second. Since only the yellow component of the light output is used for this application, better contrast is obtained by employing a yellow transmitting filter such as the Du Mont Type 216-J.

Photographic Application

Photographic applications can be divided essentially into two classes:

1. Still camera recordings of repetitive phenomena or single transients. (The Du Mont Type 271-A Oscillograph-Record Camera).

2. Recording by means of continuous-motion recorder (The Du Mont Type 314 Oscillograph-Record Camera).

The light output of the P2 screen is composed, as previously explained, of a blue short-persistent component and a yellow long-persistent component. Photographically the blue component has by far the highest actinity, i.e., it is mainly responsible for the photographic exposure. However, for most recordings with a still camera it is desirable to take full advantage of the total light output. The tube may then be used without color filters, and panchromatic films, such as Eastman 5244 (Eastman Linagraph Pan) will give best results. However, in the case of photographic recordings by means of continuous-motion cameras, blurring of the film would result from the phosphorescence of the yellow component. This can be eliminated completely by the combined use of orthochromatic (blue sensitive) film, such as Eastman 5211 (Linagraph Ortho), and blue transmitting color filter such as the Du Mont Type 216-H. The photographic efficiency of the type P2 screen is excellent and is surpassed only by the P11 screen, which is photographically about four times as efficient. The P11 screen is therefore recommended for applications where photographic recording is the main purpose, and for the specific purpose of recording oscillograms plotted at extremely high writing rates.

In addition to this performance the stability and resistance to burning of the P2 screen are excellent. However, this does not mean that no precautions against burning are to be taken. The energy of a cathode-ray beam, composed of electrons which are accelerated by high voltage, is considerable. If this energy is allowed to hit the screen in the form of a sharply focused and undeflected spot, the heat developed by bombardment of the screen material will almost immediately vaporize it. Continued bombardment of the screen will produce yellow coloration of the glass and possibly crack the tube. For high-voltage operation of cathode-ray tubes, the greatest care has to be taken to avoid having the undeflected beam hit the screen at full intensity for more than a small fraction of a second. Adequate deflection and beam-blanking circuits should be provided. The DuMont Type 281 Cathode-ray Indicator combined with the Type 286 High-Voltage Power Supply is recommended for optimum performance of the Type 5RP-A tubes.

Summary

For high-voltage operation the P2 screen gives more light output than the P1 type when used for visual observation or projection of repetitive phenomena. For fast single transients its long persistence is better than that of the P7 screen. For photographic applications the P2 material is very efficient although not as good as the Type P11 screen. The apparent persistence of the P2 screen material can be varied from short to long persistence by the use of blue or yellow transmitting filters. It appears from the foregoing that the P2 phosphor is by far the most universal

screen material for high-voltage operation, and its use is recommended for practically all applications.

It is for these reasons that it has been possible to standardize the P2 phosphor as the all-purpose screen for high-voltage oscillographic cathode-ray tubes. In addition, the P11 screen is available for the specific purpose of recording oscillograms plotted at extremely high writing rates. Accordingly, Du Mont Type 5RP-A tubes are manufactured with two standard screen types, the P2 and the P11. This reduction in the number of screen types required by laboratories using the techniques of high-voltage oscillography will help to maintain the price of each type at a reasonble level; this permits the average laboratory to maintain a stock of tubes for all requirements. Other screen types, however, may be obtained from Allen B. Du Mont Laboratories, Inc., on special order, at a price which usually will be slightly higher because of the small quantities produced.

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A NEW METHOD OF TESTING AUDIO EQUIPMENT

Once again a new measurement technique is made possible by the cathode-ray oscillograph. In a new application for testing audio equipment, oscillograms indicating the fidelity of reproduction of a sweep frequency transcription* are interpreted to obtain complete performance characteristics such as amplitude and frequency distortion, resonant peaks, transient response and mechanical distortion.

Figures 1-8 show such oscillograms for phonograph equipment tested by this method. The pick-up was connected to the input terminals of the Y-axis amplifier of the cathode-ray oscillograph,** and the time-base generator was maintained in synchronism

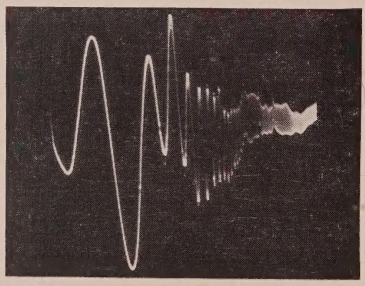

FIGURE 1—Frequency response of a crystal pick-up without equalization. The excess of base results in an accentuation of the turntable "wow" which distorts the base line.

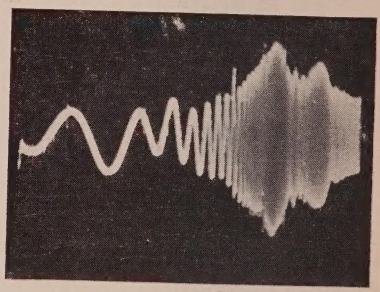

FIGURE 2—Response with equalizer (simple R-C circuit) set for maximum treble and minimum base. Turn table wow is eliminated and record scratch is noticeable.

* A recording of the frequency spectrum between 60 and 10,000 cps which is logarithmically swept at a repetition rate of 20 cps, manufactured by Clarkstan Corp., 11927 W. Pico Blvd., Los Angeles 34, Calif.

** The Du Mont Types 164-E, 208-B, 274, and 247 oscillographs are recommended for this application.

with the repetition rate of the recording. Synchronizing pulses of 200 μsec duration are included in the recording at the beginning of each repetition cycle. To facilitate a study of details, an expanded oscillograph sweep may be obtained by operating the time-base generator at a higher frequency.* The transcription also includes frequency marker pulses at one, three,

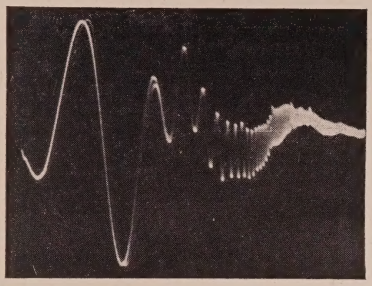

FIGURE 3—Response of the same pick-up with equalizer adjusted for maximum base and minimum treble. Turn table wow is again present but record scratch is eliminated.

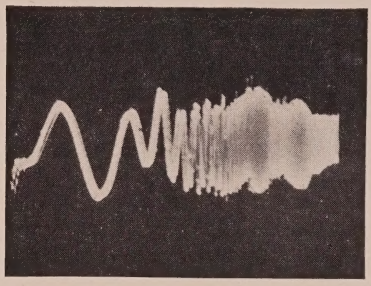

FIGURE 4—Characteristics with equalizer controls set for nearly flat response.

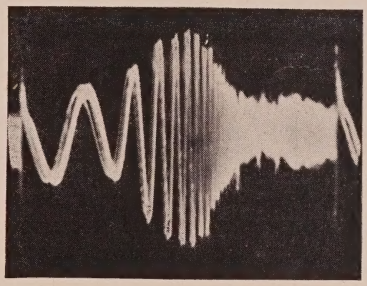

FIGURE 5—Oscillogram showing satisfactory operation of a turntable as indicated by coincidence of traces despite multiple photographic exposure.

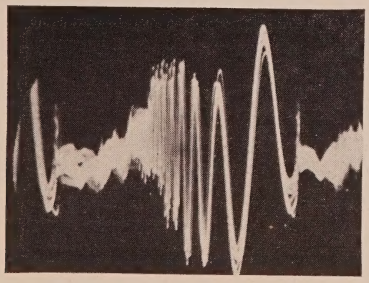

FIGURE 6—Oscillogram indicates a defective turntable. The pattern is modulated in accordance with the wobble of the turntable.

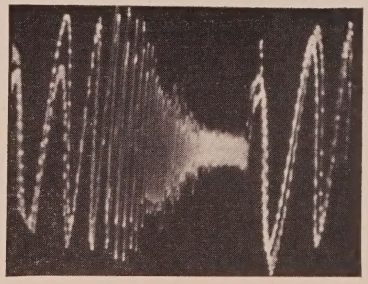

FIGURE 7—Characteristics of a pick-up with poor high-frequency response. Some wobble is noticeable, and the superimposed trace on the low frequency wave represents a noisy point. High-frequency noise is also indicated along the trace.

* See: Feldt, R., "Magnification of Details in a Complex Wave Form", Oscillographer, Vol. 7, No. 1, Jan.-Feb., 1945.

five, and seven kilocycles. These markers plus a decibel scale that may be provided along the Y-axis facilitate recording of the quantitative indications on the screen of the oscillograph.

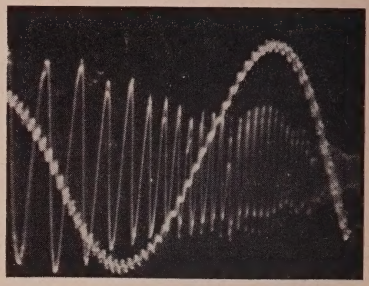

FIGURE 8—Same conditions as for Figure 7 but recorded with expanded sweep to show the high-frequency noise more clearly.

DU MONT DEMONSTRATION ROOM

The steady increase in the number of applications of electronic equipment has aroused considerable interest in cathode-ray instruments. As a result, cathode-ray oscillographs and indicators are widely used in industry and the sciences.

Realizing that many of these applications are not generally publicized, and that demonstrated examples will be of interest to those who have contemplated the use of cathode-ray instruments, Du Mont has established a Demonstration Room to show such equipment in operation.

The demonstration room is set up so that simple experiments may be performed to demonstrate the practicality of the cathode-ray method of indication. Here you can observe the latest Du Mont equipment in operation, solving problems electronically. This is an opportunity to become familiar with a new technique so that you can compare older methods with modern cathode-ray oscillography.

In addition, facilities for conferences are provided so that you may discuss your problems with our engineers. Our Applications Engineering Section is equipped to solve all problems concerning the use of cathode-ray equipment.

Demonstrations and consultations are available through personal appointment. Requests should be addressed to our Technical Sales Department, Allen B. Du Mont Laboratories, Inc., 1000 Main Avenue, Clifton, N. J.

REORGANIZATION OF SERVICE DEPARTMENT

In order to improve service to Du Mont customers, the service department of the Cathode-ray Instrument Division has been reorganized. Correspondence regarding service on Du Mont instruments and orders for spare parts will be most expeditiously handled if addressed as follows:

Instrument-Service Department
Allen B. Du Mont Laboratories, Inc.
1000 Main Avenue
Clifton, New Jersey

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